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Studies of valence-quark shadowing at HERA

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Nuclear shadowing in the structure function F_2 has been well studied [1]. Models for explaining the shadowing include vector-meson-dominance-type models and parton-recombination-type ones. The former models describe the shadowing by the transformation of a virtual photon into vector-meson states or $q\bar{q}$ states, which then interact with a target nucleus. The central constituents are "shadowed" due to the existence of nuclear surface constituents. The latter models explain the shadowing by interactions of partons from different nucleons in a nucleus. They become important especially at small x, where the longitudinal localization size of a parton exceeds the average nucleon separation in the nucleus.

Because these different models produce similar x and Q^2 dependence in the structure function F_2, we cannot distinguish among the models in comparison with experimental data. Various shadowing models may be tested by other quantities such as sea-quark and gluon distributions in nuclei [2]. However, valence-quark distributions could be useful in determining the appropriate shadowing description [3].

We propose to measure the valence-quark shadowing by observing charged pion productions in electron-nucleus scattering at HERA. In fact, charged hadron productions have been used for finding the u-valence-quark distribution [4]. However, there is no accurate data in discussing the shadowing at this stage. In order to illustrate theoretical issues, two different models are employed.

The first one is a hybrid parton model with Q^2 rescaling and parton recombination effects [1]. According to the Q^2 rescaling model, nuclear valence-quark distribution $V_A(x,Q^2)$ is given by rescaling (increasing) Q^2 in the nucleon distribution $V_N(x,Q^2)$. Therefore, the ratio $R_V \equiv V_A(x)/V_D(x)$ is smaller than unity at medium x as it explains the EMC effect in this region. Since the rescaling satisfies the baryon-number conservation $\int dxV(x) = 3$, the ratio R_V becomes larger than unity at small x. Parton-recombination contributions are rather contrary to those in the rescaling model in the sense that the recombinations decrease the ratio at small x and increase it at medium and large x. The overall effects are shown by a solid line (model 1) in Fig. 1. In this parton model, the valence-quark shadowing differs distinctively from the F_2 one: $V_A(x)/V_N(x) \neq F_2^A(x)/F_2^N(x)$ at small x.

The second model is the aligned jet model in Ref. [5]. The model prediction for the valence shadowing is shown by a solid curve (model 2) in Fig. 1. This shadowing is very similar to the F_2 shadowing: $V_A(x)/V_N(x) \approx F_2^A(x)/F_2^N(x)$ at small x. It is because

the $q\bar{q}$ pair interacts with sea and valence quarks in the similar way. The model curve is obtained by the aligned-jet-model together with the baryon-number conservation.

There is little experimental information on the valence shadowing from neutrino data, so that we estimate a current experimental restriction on the valence shadowing by using F_2^A/F_2^D ($\equiv R_2$) data at medium x and the baryon number conservation. In finding the restriction, we assume $R_V = R_2$ in the region $x \geq 0.3$ because valence-quark distributions dominate the F_2 structure functions. We employ SLAC R_2^{Ca} data, which are fitted by a smooth curve. This curve is extrapolated into the small x region by using the baryon-number conservation. We find that the shaded area is roughly the possible nuclear modification, which is allowed by present experimental data of R_2.

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Fig. 1 Valence-quark "shadowing".

The models predict completely different behavior at small x: antishadowing in the first parton model and shadowing in the aligned-jet model. So the models are two extreme cases, which are both acceptable in our present knowledge as shown in Fig. 1. We have not investigated the details of other model predictions. However, it is very encouraging to investigate the (anti)shadowing phenomena of the valence-quark distribution in the sense that the observable could be useful in discriminating among various models, which produce similar results in the F_2 shadowing.

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